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METHOD AND DEVICE FOR DRIVING SUPPORT ROLLS OF A CONTINUOUS CASTING MACHINE FOR LIQUID METALS, ESPECIALLY LIQUID STEEL MATERIALS

The invention concerns a method and a device for driving the support rolls of a continuous casting machine for liquid metals, especially liquid steel materials, which support rolls form a strand guide for the continuously cast strand, which strand guide consists of electrically driven individual support rolls and/or hydraulically adjustable support roll segments, wherein an automatic load balance control system for the drives is used as the sum of the functions of casting speed, motor torque, motor speed, and standard correction factors and is provided with individual adjustment of the torque and speed of each drive support roll motor.

The strand guide for the continuously cast strand, which is cast in billet, slab, thin-slab, preliminary-section, or ingot format, simultaneously serves as a withdrawal device which withdraws the continuously cast strand emerging from the continuous casting mold through the strand guide against the resistance it offers. The strand guide comprises idle (not

driven) support rolls and driven drive support rolls positioned opposite a support roll. The drive support rolls transmit both guide forces and strand conveyance forces in cooperation with the dragged support rolls and are pressed against the continuously cast strand with a well-defined contact force. All of the drive support rolls together overcome the forces of resistance to withdrawal to which the strand is subjected on its way through the strand guide.

The power of these drives is generally adjusted in such a way that, on the one hand, reliable withdrawal of the continuously cast strand is guaranteed in every conceivable operating situation, but, on the other hand, the production costs and operating costs are kept as low as possible, and the drives are not needlessly overdimensioned.

Two different methods are known for the transmitting driving torques of the individual drives to the continuously cast strand.

In the first method, the drives are manually adjusted and then left to themselves during the operation.

In a second method (see Figure 1 on the state of the art), the sum of the driving torques (M_1 - M_n) of all active drives is determined, and the mean value is taken. This mean value is fed back as the set driving torque to each drive. By means of an

automatic load balance control system, an attempt is made to adjust the delivered driving torque to the set value by making speed changes ($n_{set} - n$) in the given drive.

Both control methods have the disadvantage that the driving torques are not assigned according to the forces or torques that can actually be transmitted. The result of this is that drives are able to apply only a smaller torque than the set torque and thus permanently rotate at a greatly increased speed due to their low normal force, whether as the result of roll wear or technological limitations, and this means that the drive rolls are subject to increased wear.

Another disadvantage is that in the case of drives that could transmit more than the mean torque when a process-related short-term increase in the resistance to withdrawal arises and a higher total torque is required, only the mean value of the total torque is called up, i.e., these drives are asked to deliver less torque than they could, while other drives are unable to transmit the required set torque for the reasons specified above. This process can lead to stoppage of the continuously cast strand, which results in a discontinuation of casting with large losses.

EP 0 463 203 B discloses a guide method for the electric drives of rolls of a continuous casting plant, wherein the

continuously cast strand is drawn from the continuous casting mold by the driven rolls, whose drives are individually automatically controlled by automatic controllers, and wherein the set point assignment for the roll drives is made as a function of load, for example, via the speed assignment. This is intended to achieve load balance among the individual roll drives. However, this method does not take into consideration either situations that are operationally related or a total expenditure of power, which allows control of the total driving force that is to be applied in normal cases according to experience.

JP 2003 033854 A (abstract) discloses a method and a device for driving a support roll of a continuous casting machine for liquid metals with individual adjustment of torque and speed. To this extent, the known design corresponds to the general type described above.

In JP 11[1999]-151,558 A (abstract), the well-known method and the well-known device are provided with individual adjustment of torque and speed of each drive support roll motor. However, they do not eliminate the disadvantage that drives are able to apply only a smaller torque than the set torque and thus permanently rotate at a greatly increased speed due to their low normal force, whether as the result of roll wear or

technological limitations, which means that the drive rolls are subject to increased wear. Therefore, a previously known torque compensating calculator for adjusting the load torque of each driving roll is not sufficient for determining a necessary total drive torque.

The objective of the invention is to distribute to the drives the total driving torque that is to be applied in normal cases according to their natural transmission capacity on the basis of the normal force of each support roll and drive support roll.

In accordance with the invention, this objective is achieved by determining a total driving torque for all drives from the normal force of the driven support rolls and proportionately transmitting it to each support roll and by using a static base setting of the torque distribution as the basis for the specific load capacity of each drive support roll. On the one hand, this prevents unnecessary racing of the drive support rolls. On the other hand, it guarantees that the maximum possible driving torque can actually be transmitted to the cast strand by the drive rolls. In addition, roll wear is significantly reduced. The method can be used not only in conventional strand support roll segments with a separately adjustable drive support roll, but also in support roll segments

with the drive roll integrated in the top frame (CyberLink segments), in a pure drive by means of driving rolls, and in mixed forms of drive variants.

In a refinement of the invention, the specific load capacity of a drive support roll is determined from the geometry of the strand guide, the ferrostatic head, and/or the distance between the rolls.

In accordance with other features of the invention, the set values are corrected by feedback to the automatic load balance control system of the current contact forces of the piston-cylinder units of a strand support roll segment or a drive support roll and operational values of the casting format.

In a further refinement of the invention, these correction values can be used to obtain a dynamic factor derived from the contact forces of the individual torques and from the individual speeds for the preassigned torque value for each drive from the ratio of the current normal force of the drive support roll to the theoretical normal force.

Furthermore, an additional correction factor for the roll wear and the friction conditions between the cast strand and the support rolls or drive support rolls can be taken into account. An additional criterion of the previously existing deviations can be determined in this way.

According to other features of the invention, the accuracy of the automatic control method can be enhanced by considering an unweighted overall factor formed from the specific load capacity, the dynamic factor, and the additional correction factor.

Another refinement takes into consideration a weighted overall factor formed from the unweighted overall factor by multiplication with the ratio of the number of all active drives to the sum of all unweighted factors of all active drives.

In accordance with other features, a closed-loop control system is provided for each drive and is supplied with the mean value of the driving torques of all active drives and of the set-point speed.

Building on this, the mean value, together with the weighted overall factor in each case, is supplied to the automatic controllers as a set point, and each automatic controller converts it to a speed set point.

Another special feature is that, for the determination of the mean value or the summation of the driving torques, only those drives are considered which are suitable for the transmission of the driving torque.

In cases in which the process situation allows a measure of this type, it is provided that the current contact forces of the

piston-cylinder units for the strand support roll segments or of the drive support rolls or of the piston-cylinder units of the drive support rolls are increased until the required driving torque is transmitted.

A prior-art device for driving drive support rolls of a continuous casting machine for liquid metals, especially liquid steel materials, comprises a strand guide for the continuously cast strand, which strand guide consists of electrically driven individual drive support rolls and/or hydraulically adjustable strand support roll segments, wherein an automatic load balance control system for the drives is developed as the sum of the individual forces for casting speed, motor torque, motor speed, and standard correction factors and is provided with individual adjustment of the torque and speed of each drive support roll motor.

In accordance with the invention, the device for achieving the objective of the invention is characterized by the fact that the automatic load balance control system has a computer block for determining the torque distribution, whose input variables consist at least of the number "n" of active drives and the load capacity of the individual drive support rolls, wherein processing values expressed by the plant-specific design of the strand guide and the geometric data of the continuously cast

strand are input, and that information about the state of wear of the drive support rolls and the current contact forces F and the current driving torques M are used as input variables.

In a refinement of the basic idea of the invention, a set point M is determined in the computer block from the input variables and introduced into each torque controller as an input variable.

In accordance with additional features, each torque controller is connected to a speed controller, to which a correction speed for the electric motor is transmitted.

A specific embodiment of the invention is illustrated in the drawings and explained in greater detail below.

-- Figure 1 shows a general side view of a continuous casting plant with an automatic load balance control system in accordance with the present state of the art.

-- Figure 2 shows the same general side view of the continuous casting plant with an automatic load balance control system in accordance with the invention.

-- Figure 3 shows a functional block diagram of the automatic load balance control system.

The continuously cast strand (Figures 1 and 2) is formed in the continuous casting process, in which the liquid metal, especially liquid steel material, is conveyed from the ladle 2

through a tundish 3, a strand shell forms in the continuous casting mold 4 by cooling, and the strand is conveyed further, cooled further, and withdrawn.

In contrast to the prior art (Figure 1), in accordance with the invention (Figure 2), a strand guide 7 for the continuously cast strand 1 is formed by a segment (without adjustment and without driving of the support rolls), followed by segments 6 with idly rotating support rolls 7a with suitable roll separation 7b and independently adjusted drive support rolls 7c. The drive support rolls 7c are equipped with a drive 10, which, for rotating support rolls, consists of an electric motor 8, and for a strand support roll segment 9 (consisting of a set of idle support rolls 7a), there is an individual electric motor 8 for each drive support roll 7c. A hydraulic piston-cylinder unit 11 for adjusting individual support rolls 7a and drive support rolls 7s is also designated as a drive 10.

In an automatic load balance control system 12 (Figure 1), the sum of the driving torques M_1 - M_n of all active drives 10 is computed, and the mean value is taken. This mean value is fed back to each drive 10 as the set-point driving torque $M_{set\ n}$. An attempt is made by means of one controller each (in the automatic load balance control system 12) to adjust the delivered driving torque of the respective drive to the set

point by speed changes $n_{set\ n}$ of the respective drive 10. The correcting values are the speed set point and the torque set point.

In contrast to the prior art (Figure 1), Figure 2 shows a method for driving drive support rolls 7c of the illustrated continuous casting machine as an example of a continuous slab-casting installation for liquid metals, especially liquid steel materials, in which the strand guide 7 for the continuously cast strand 1 is formed by electrically driven, individual drive support rolls 7c and by hydraulically adjustable strand support roll segments 9, wherein the automatic load balance control system 12 for the drives is assumed as the sum of the individual forces for casting speed, motor torque, motor speed, and standard correction factors.

The total driving torque for all drives 10 is determined from the normal force of the driven drive support rolls 7c and transmitted proportionately to each drive support roll 7c according to the local conditions, such that a static base setting of the torque distribution is used as the basis for the specific load capacity of each drive support roll 7c. The specific load capacity of a driven support roll 7c is determined from the geometry of the strand guide 7 (e.g., a bow-type continuous casting installation), the ferrostatic head (height

difference of the liquid strand core to the liquid metal level of the continuous casting mold 4), and/or the roll separation. The current contact forces F_1 - F_n of the piston-cylinder units 11 of a strand support roll segment 9 or of a drive support roll 7c and functional values of the casting format are fed back to the automatic load balance control system 12. A dynamic factor derived from the contact forces F_1 - F_n of the individual torques and from the individual speeds n_{1-n} for the preassigned torque value for each drive 10 is obtained from the ratio of the current normal force of the drive support rolls 7c to the theoretical normal force.

An additional correction factor for the roll wear and the friction conditions between the cast strand 1 and the support rolls 7a or drive support rolls 7c can also be taken into account. In addition, an unweighted overall factor formed from the specific load capacity, the dynamic factor and the additional correction factor can be considered. In this regard, a weighted overall factor is formed from the unweighted overall factor by multiplication with the ratio of the number of all active drives 10 to the sum of all unweighted factors of all active drives 10 and then taken into consideration.

A closed-loop control system is provided for each drive 10 (drive support rolls 7c and/or hydraulic piston-cylinder unit

11) and is supplied with the mean value of the driving torques of all active drives 10 and of the set-point speed n_{set}. The mean value, together with the weighted overall factor in each case, is supplied to the automatic controllers as set point M_{set}, and each automatic controller converts it to a speed set point n_{set}. In this regard, for the determination of the mean value or the summation of the driving torques, only those drives 10 are considered which are suitable for the transmission of the driving torque, i.e., capable of transmission.

In addition, the current contact forces $F_1 - F_n$ of the piston-cylinder units 11 for the strand support roll segments 9 or of the drive support rolls 7c or of the piston-cylinder units 11 of the drive support rolls 7c can be increased until the required driving torque is transmitted.

The automatic load balance control system 12 (Figure 3) has a computer block 13 for determining the torque distribution, whose input variables 14 consist of the number of active drives "n", values for the plant-specific design of the strand guide 7, geometric data of the continuously cast strand 1, state of wear of the drive support rolls 7c, and the contact forces F with the actual value. The load capacity of the individual drive support rolls 7c is also taken into account in making this determination. Processing values are provided for the plant-

specific design of the strand guide 7 and the geometric data of the continuously cast strand 1. Information about the state of wear of the drive support rolls 7c and the current contact forces F and the current driving torques M are used as additional input variables 14. A set point M is determined in the computer block 13 from the input variables and introduced into each torque controller as an input variable 16. In addition, each torque controller 15 is connected to a speed controller 17, to which a correction speed 18 for the electric motor 8 is transmitted.

List of Reference Numbers

1	continuously cast strand
2	ladle
3	tundish
4	continuous casting mold
5	segment without adjustment and without driving of the support rolls
6	segment with independently adjusted drive support roll

7 strand guide

7a support rolls, idle

7b roll separation

7c drive support rolls

8 electric motor

9 strand support roll segment

10 drive

11 hydraulic piston-cylinder unit

12 automatic load balance control system

13 computer block

14 input variable

15 torque controller

16 input variable

17 speed controller

18 correction speed

CLAIMS

1. Method for driving the support rolls (7c) of a continuous casting machine for liquid metals, especially liquid steel materials, which support rolls form a strand guide (7) for the continuously cast strand (1), which strand guide consists of electrically driven individual support rolls (7c) and/or hydraulically adjustable support roll segments (9), wherein an automatic load balance control system (12) for the drives (10) is used as the sum of the individual forces for casting speed, motor torque, motor speed, and standard correction factors and is provided with individual adjustment of torque and speed of each drive support roll motor, characterized by the fact that a total driving torque for all drives (10) is determined from the normal force of the driven drive support rolls (7c) and proportionately transmitted to each support roll (7c) in such a way that a static base setting of the torque distribution is used as the basis for the specific load capacity of each drive support roll (7c).

2. Method in accordance with Claim 1, characterized by the fact that the specific load capacity of a drive support roll (7c) is determined from the geometry of the strand guide (7), the ferrostatic head, and/or the roll separation (7b).

3. Method in accordance with Claim 1 or Claim 2, characterized by the fact that the current contact forces (F_1 - F_n) of the piston-cylinder units (11) of a strand support roll segment (9) or of a drive support roll (7c) and oprational values of the casting format are fed back to the automatic load balance control system (12).

4. Method in accordance with Claim 3, characterized by the fact that a dynamic factor derived from the contact forces (F_1 - F_n) of the individual torques (M_{1-n}) and from the individual speeds (n_{1-n}) for the preassigned torque value for each drive (10) is obtained from the ratio of the current normal force of the drive support roll (7c) to the theoretical normal force.

5. Method in accordance with any of Claims 1 to 4, characterized by the fact that an additional correction factor for the roll wear and the friction conditions between the cast strand (1) and the support rolls (7a) or drive support roll (7c) is taken into account.

6. Method in accordance with any of Claims 1 to 5, characterized by the fact that an unweighted overall factor formed from the specific load capacity, the dynamic factor, and the additional correction factor is taken into consideration.

7. Method in accordance with Claim 6, characterized by the fact that a weighted overall factor is formed from the unweighted overall factor by multiplication with the ratio of the number of all active drives (10) to the sum of all unweighted factors of all active drives (10) and taken into consideration.

8. Method in accordance with any of Claims 1 to 7, characterized by the fact that a closed-loop control system is provided for each drive (10) and is supplied with the mean value of the driving torques of all active drives (10) and of the set-point speed (n_{set}).

9. Method in accordance with Claim 7 and Claim 8, characterized by the fact that the mean value, together with the weighted overall factor in each case, is supplied to the automatic controllers as a set point (M_{set}), and each automatic controller converts it to a speed set point (n_{set}).

10. Method in accordance with Claim 8 or Claim 9, characterized by the fact that for the determination of the mean value or the summation of the driving torques, only those drives (10) are considered which are suitable for the transmission of the driving torque.

11. Method in accordance with Claim 8 or Claim 9, characterized by the fact that the current contact forces (F_1 - F_n) of the piston-cylinder units (11) for the strand support roll segments (9) or of the drive support rolls (7c) or of the piston-cylinder units (11) of the drive support rolls (7c) are increased until the required driving torque is transmitted.

12. Device for driving drive support rolls (7c) of a continuous casting machine for liquid metals, especially liquid steel materials, comprising a strand guide (7) for the continuously cast strand (1), which strand guide (7) consists of electrically driven individual drive support rolls (7c) and/or hydraulically adjustable strand support roll segments (9), wherein an automatic load balance control system (12) for the drives (10) is developed as the sum of the individual forces for casting speed, motor torque, motor speed, and standard correction factors and is provided with individual adjustment of the torque and speed of each drive support roll motor (8), characterized by the fact that the automatic load balance control system (12) has a computing unit (13) for determining the torque distribution, whose input variables (14) consist at least of the number "n" of active drives (8, 11) and the load capacity of the individual drive support rolls (7c), wherein

processing values expressed by the plant-specific design of the strand guide (7) and the geometric data of the continuously cast strand (1) are input, and that information about the state of wear of the drive support rolls (7c) and the current contact forces F_{1-n} and the current driving torques $M_{actual,1-n}$ are used as input variables (14).

13. Device in accordance with Claim 12, characterized by the fact that a set point $M_{set,1-n}$ is determined in the computing unit (13) from the input variables (14) and introduced into each torque controller (15) as an input variable (16).

14. Device in accordance with Claim 12 and Claim 13, characterized by the fact that each torque controller (15) is connected to a speed controller (17), to which a correction speed (18) for the electric motor (8) can be transmitted.

Figure 1 (State of the Art)

KEY:

$V_{gieß}$ = V_{cast}

n_{soll} = n_{set}

M_{soll} = M_{set}

Korrekturwerte = correction values

Figure 2

See fig 1

Belastbarkeit = load capacity

Figure 3

subscripts: ist = actual;

soll = set

Drehzahlregler = speed controller

Block zur Ermittlung der Momentenverteilung = block for determining the torque distribution

Anzahl Antriebe n = number of drives n

Anlagenspezifische Ausführung der Strangführung = plant-specific design of the strand guide

Geometriedata des Produktes = geometric data of the product

Verschleißzustand der Antriebsrolle = state of wear of the drive roll

Anstellkräfte F_ist_{1-n} = contact forces F_actual_{1-n}

Momentenregler = torque controller